

EXHIBIT M  
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## EXHIBIT N



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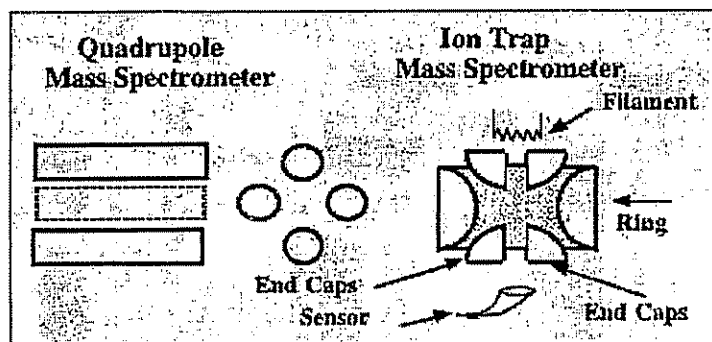
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### [Alphabetical Index of Chromatography Topics](#)



**Figure 28. Pole Arrangement for the Quadrupole and Ion Trap Mass Spectrometers**

**Figure 28. Pole Arrangement for the Quadrupole and Ion Trap Mass Spectrometers**

It was shown in figure 18, that the quadrupole spectrometer contains four rod electrodes. The ion trap mass spectrometer (figure 21) has a quite different electrode arrangement, which consists of three cylindrically symmetrical electrodes comprised of two end caps and a ring. The pole system can be made very small; the opposite internal electrode faces being only 2 cm apart. Each electrode has *accurately machined hyperbolic internal faces*. In a similar manner to the quadrupole spectrometer, an rf voltage together with an additional DC voltage is applied to the ring and the end caps are grounded.

In the same way as the quadrupole mass spectrometer, the rf voltage causes rapid reversals of field direction, so any ions are alternately accelerated and decelerated in the axial direction and *vice versa* in the radial direction. There are operating parameters, (a), and (q), that define the conditions of oscillation which are analogous to those for the quadrupole mass spectrometer but, in this case, ( $r_0$ ) is the internal radius of the ring electrode. As already stated, the ion trap is small

and ( $r_0$ ) is typically only about 1 cm. At a given voltage, ions of a specific mass range are held oscillating in the trap. Initially, the electron beam is used to produce ions and after a given time the beam is turned off. All the ions, (*except* those selected by the magnitude of the applied rf voltage) are lost to the walls of the trap, and the remainder, continue oscillating within the trap. The potential of the applied rf voltage is then increased, and the ions sequentially assume unstable trajectories and leave the trap via the aperture to the sensor. The ions exit the trap in order of their increasing m/z values. The early ion trap mass spectrometers were not very efficient, but it was found by introducing traces of helium into the ion trap stabilized the system and significantly improved the quality of the spectra. This improvement was explained on the basis of ion-helium collisions that reduced the energy of the ions and allowed them to concentrate in the center of the trap. The spectra produced have proved to be quite satisfactory for solute identification by comparison with reference spectra. However, the spectrum produced for a given substance will probably differ considerably from that produced by the normal quadrupole mass spectrometer.

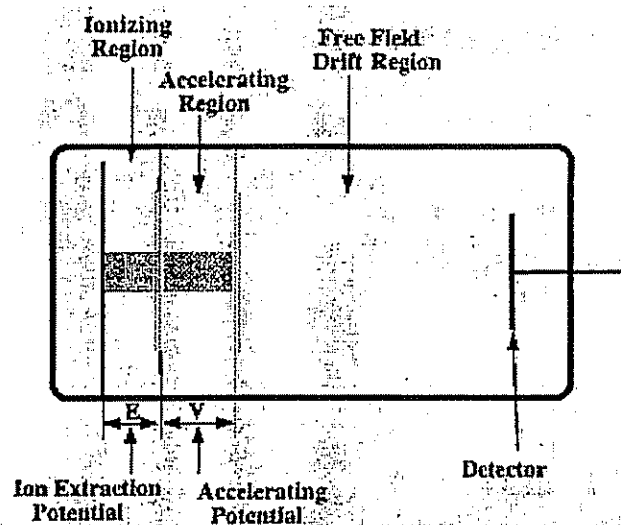
### The Time of Flight Mass Spectrometer

The time of flight mass spectrometer was invented many years ago but, due to the factors controlling resolution not being clearly recognized and also due to certain design defects that occurred in the first models, it exhibited limited performance and was rapidly eclipsed by other developing mass spectrometer techniques. However, with improved design, modern fabrication methods and the introduction of Fourier transform techniques, the performance has been vastly improved. As a result, there has been a resurgence of interest in this particular form of mass spectrometry. A diagram of the time of flight mass spectrometer is shown in figure 29.

In a time of flight mass spectrometer the following relationship holds,

$$t = \left( \frac{m_i}{2zeV} \right)^{\frac{1}{2}} L$$

where (t)	is the time taken for the ion to travel a distance (L)
(V)	is the accelerating voltage applied to the ion,
and (L)	is the distance traveled by the ion to the ion sensor.



**Figure 29. The Time of Flight Mass Spectrometer**

It follows, that for a given system, the mass of the ion is directly proportional to the square of the transit time to the sensor. The sample is volatilized (or passed as a vapor) into the space between the first and second electrodes and a burst of electrons (over a period of about a microsecond) is allowed to produce ions. An extraction potential ( $E$ ) is then applied for another short time period which, as those further from the second electrode will experience a greater force than those closer to the second electrode, will result in the ions being focused.

After focusing, an accelerating potential ( $V$ ) is applied for a much shorter period than that used for ion production (ca 100 nsec) so that all the ions in the source are accelerated virtually simultaneously. The ions then pass through the third electrode into the *drift zone* and are eventually collected by the sensor electrode. The time of flight mass spectrometer is not employed extensively in gas chromatography/mass spectroscopy combination systems as it is more commonly used to examine high molecular weight materials

Many analysts that use GC/Mass Spectrometer combined systems are neither specialists in gas chromatography or mass spectrometry and may need the support of experienced gas chromatographers or mass spectroscopists for particularly challenging samples. For those who wish to study mass spectrometry further, an excellent discussion on general organic mass spectrometry is given in *Practical Organic Mass Spectrometry* edited by Chapman (9).

## Gas Chromatography IR Spectroscopy (GC/IR) Systems

IR spectra were initially obtained off-line, by condensing the eluted solute in a cooled trap, making into a 'mull', or pressing into an alkali halide pellet and the spectrum obtained using standard techniques. Collection of a solute by condensation, however, can be difficult as, due to the very low concentrations at which each solute is eluted, the partial pressure of the condensed material is often similar to its partial pressure as it leaves the GC column. An efficient method to collect the solute is to use argon as the carrier gas, and condense the argon and the solute simultaneously in a tube cooled with liquid nitrogen. The trapping efficiency can also be improved by trapping the solute on an adsorbent contained in a short length of packed tube and regenerated in a stream of hot gas or by solvent extraction.

The first fully automated on-line GC/IR system was that developed by Scott *et al.* (10). Each eluted solute was adsorbed in a cooled packed tube, and then thermally regenerated into an infrared vapor cell. Subsequent to the IR spectrum being obtained, a small sample of the vapor was drawn from the IR cell into a low-resolution mass spectrometer and the mass spectrum was also taken.

This system was not a tandem system but, in fact, the first triplet instrument to be reported (GC/IR/MS). The layout of the pneumatic system of the triplet instrument is shown in figure 30. The procedure for analyzing a peak was as follows. As the peak started to elute it was sensed by the detector and the exit carrier gas diverted through the IR cell into a packed trap which concentrated the peak onto the front of the trap packing. After peak elution was complete, the flow of carrier gas was stopped and the solute regenerated back into the IR cell by heating the trap in a secondary stream of nitrogen.

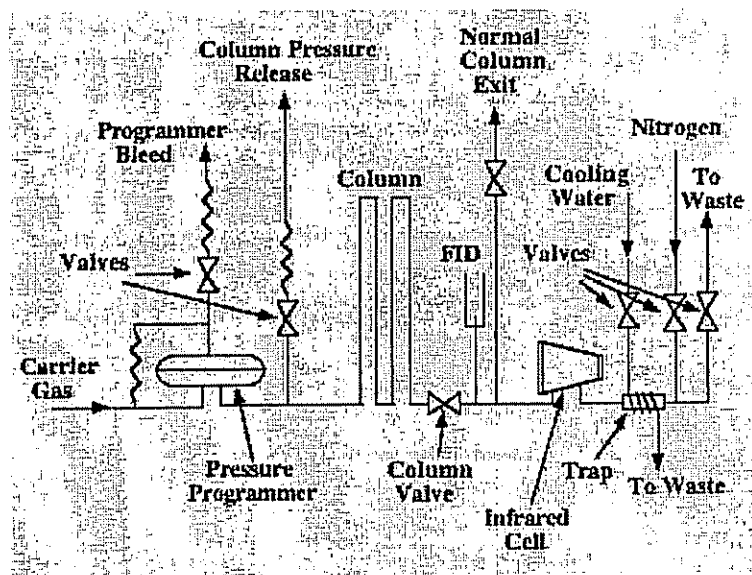


Figure 30. Diagram of an Automatic GC/IR Tandem System

TB 68

gas chromatography detector chromatography standard

column

helium

carrier gas

support

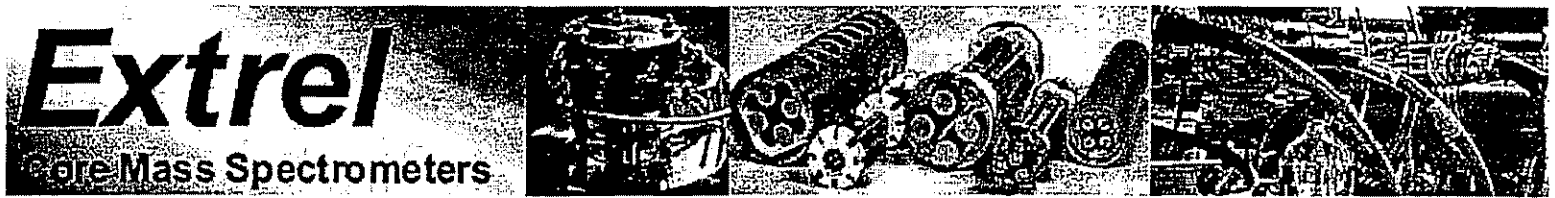
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*Previous: Ion-Trap-Detector (page 1)*

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## EXHIBIT O





## Products

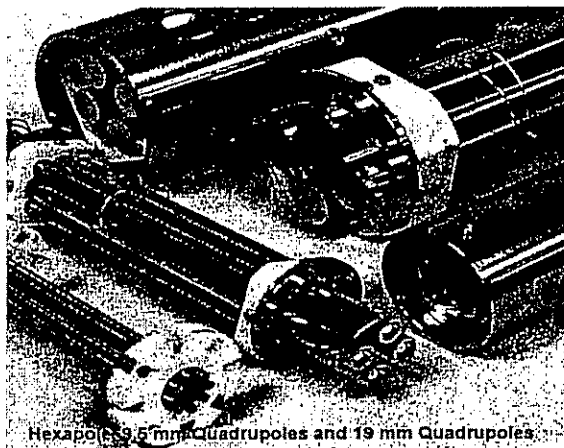
QUADRUPOLES MASS FILTERS, MS/MS COMPONENTS, OCTUPOLE ION GUIDES

Product Note List  
Add-On MAX, QMS  
APIMS  
Chamber Special  
Ionizer Ion Optics  
Energy Filters  
Quads, Oct. MS MS  
Flanges Detection  
Controllers Software  
Power Supplies  
Custom Systems

## QMS

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## Quadrupole Mass Filters



Hexapole 9.5 mm Quadrupoles and 19 mm Quadrupoles

- High Transmission
- High Sensitivity
- High Resolution
- High Abundance Sensitivity
- Rugged Design
- Bakable to 300° C
- Many Design Configurations

Extrel CMS is unique in providing high performance Quadrupole Mass Filters as separate items. We offer three different sizes of Mass Filters to meet a wide range of application requirements and mass ranges. They are available both with and without housings and with and without Pre- and post- Quadrupole Ion Optics.

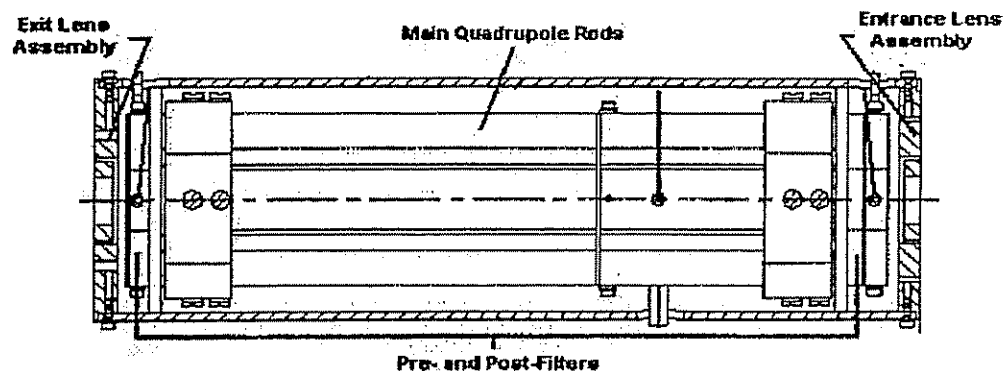
All of our Mass Filters are designed and tested to meet the highest performance standards.

### Quadrupole Construction

The Extrel CMS Tri-Filter Quadrupole Mass Filter is a high precision device designed to provide the highest possible ion transmission with the best possible Abundance Sensitivity. This combination makes the Extrel CMS Tri-filter Quadrupole the best choice for applications requiring the very best Resolution and Sensitivity.

Figure 3 below shows the main components of an Extrel CMS Tri-filter Quadrupole Mass Filter. In addition to the high precision main quadrupole rods, the mass filter also has Pre- and Post-filters. These are short stub rods before and after the the main rods that help to collimate the ions coming into and exiting the main rods to improve Abundance Sensitivity. The Pre- and Post-Filters also increase the ion transmission through the Mass Filter by shielding the ions from the RF and DC fringing fields presnet at the end of the main rods.

Tri-filter Quadrupole Mass Filters purchased with housings also have Entrance and Exit Lenses. The Entrance and Exit Lenses also aid in the transmission of the ions through the RF and DC fringing fields and in improving Abundance Sensitivity.



### Quadrupole Mass Filter Selection Chart

Mass Range, Sensitivity, Abundance Sensitivity, and Resolution are determined by the quadrupole rod size and the RF operating frequency. Increasing quadrupole rod size or operating frequency increases the Sensitivity, Abundance Sensitivity, Resolution, and High Energy Ion Transmission and Filtering. Decreasing the quadrupole rod size or the RF operating frequency increases the mass range. Application Notes on Quadrupole Mass Filter Operation are available in the Apps Note section. For detailed information on Quadrupole Mass Filters ask for Product Note RP\_2010 "Quadrupole Mass Filters".

QUADRUPOLE ROD DIAMETER	RF FREQUENCY	MAXIMUM MASS	SENSITIVITY	ABUNDANCE SENSITIVITY	RESOLUTION
6 mm (1/4 inch)	0.88 MHz	9000+	Fair	Fair	Low
9.5 mm (3/8 inch)		4000	Fair	Fair	Fair
19 mm (3/4 inch)		1000	Good	Fair	Good
9.5 mm (3/8 inch)	1.2 MHz	2000	Fair	Good	Good
19 mm (3/4 inch)		500	Fair	High	High
9.5 mm (3/8 inch)	2.1 MHz	500	Fair	High	High
19 mm (3/4 inch)		120	High	Excellent	High
9.5 mm (3/8 inch)	2.9 MHz	250	Good	High	High
19 mm (3/4 inch)		64	Excellent	Excellent	Excellent

### MS/MS Components

In addition to single Quadrupole Mass Filters Extrel CMS also offer multiple Quadrupole Hexapole and Octupole MS/MS components for Ion Chemistry Experiments, High Sensitivity Gas Analysis and Biomolecule Analysis. These include:

- Double Quadrupoles
- Triple Quadrupoles and QOQ devices with a High Pressure Collision Cells
- Ion Deflectors and Special Ion Optics for Multiple Technique Systems
- Customized Multiple Quadrupole, Hexapole and Octupole Devices

### Ion Guides and Collision Cells

RF only Hexapole and Octupoles, as ion guides, are used in various applications, such as collision cells for collision Induced dissociation, for collisional damping, focusing ion beams into smaller cross sectional areas and for simply transporting ions from one part of a vacuum system to another.

Extrel CMS offers standard and custom length Hexapoles and Octupole Ion Guides and Collision

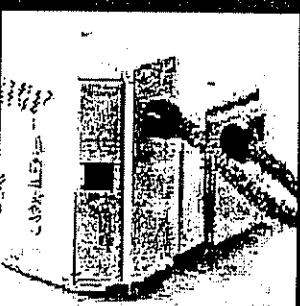
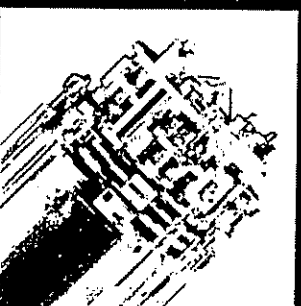
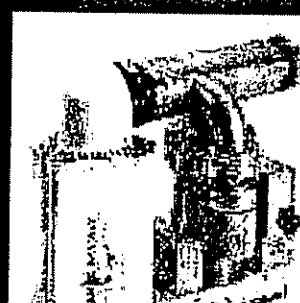
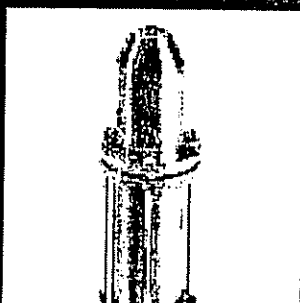
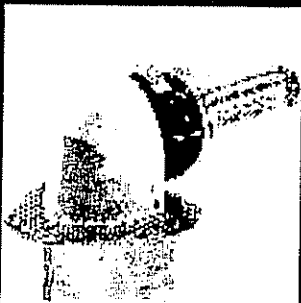
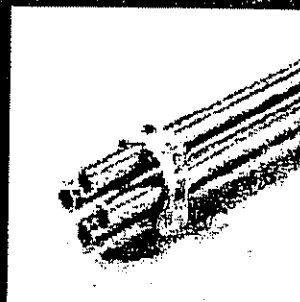
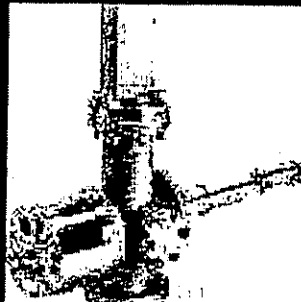
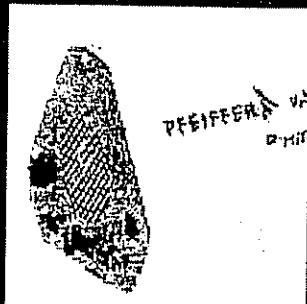
Cells. For detailed information ask for Product Notes RP\_2601, "*Ion Guides*" and RP\_2602, "*Hexapole Collision Cell*".

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## EXHIBIT P

**PFEIFFER**  **VACUUM**

# Mass spectrometer

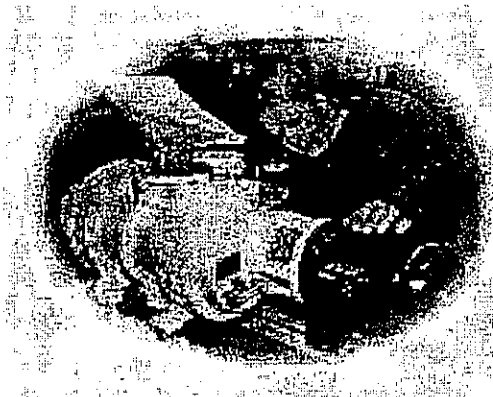


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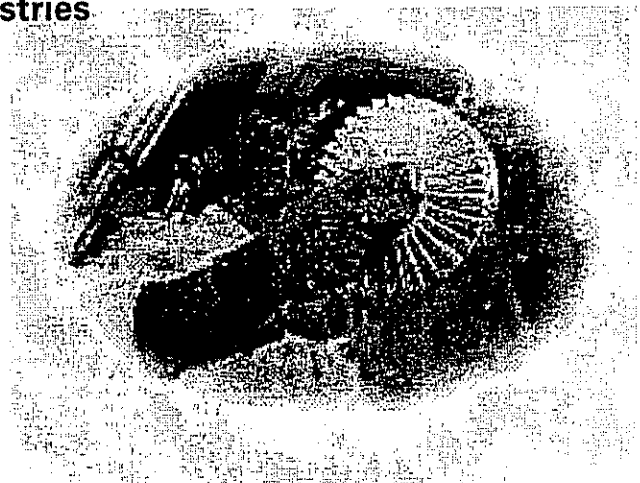
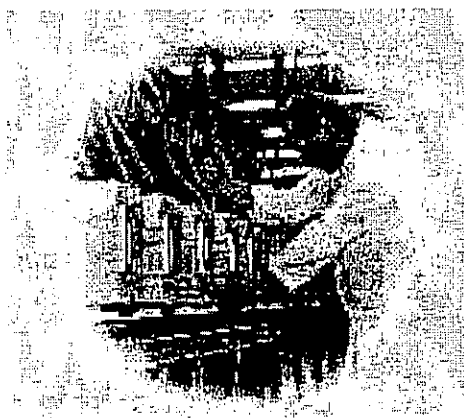
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# Vacuum is nothing, but everything to us



- ▶ Analytical instruments
- ▶ Biotechnology
- ▶ Research and Development
- ▶ Glass coating
- ▶ Semiconductor industry
- ▶ Medicine and Life Science
- ▶ Pharmaceuticals
- ▶ Process technology
- ▶ Tool coating
- ▶ Additional markets such as  
packaging and automotive  
industries



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Fundamentals

Residual gas analysis

Gas analysis

Analysis of ions

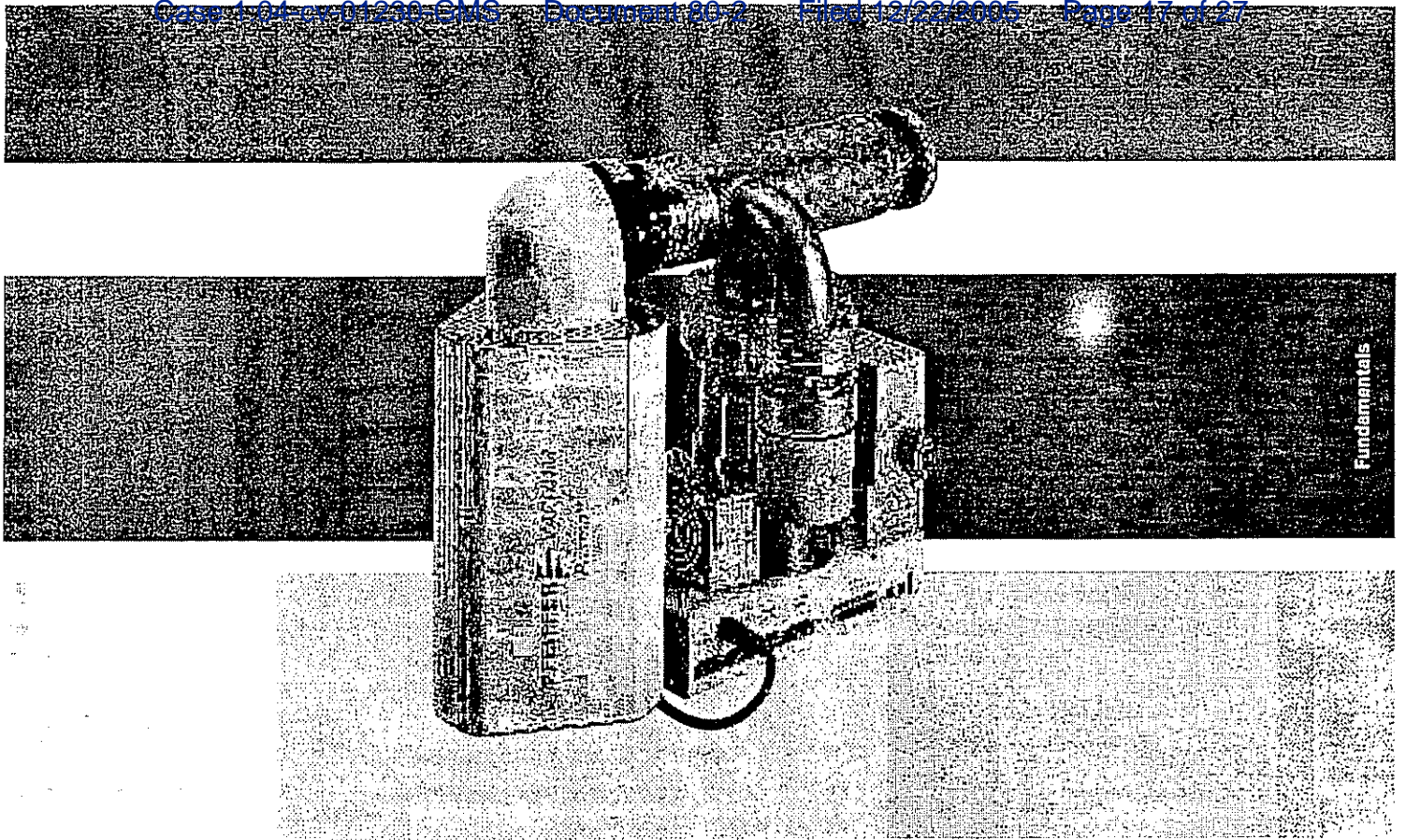
Appendix

# 1 Fundamentals of mass spectrometry

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# 1 Fundamentals of mass spectrometry



## 1.1 Introduction

Mass spectrometric measuring methods have become an indispensable diagnostic aid in numerous branches of process engineering, technology and product development, medicine and basic scientific research.

versely, development of vacuum technologies has increasingly required the utilization of small high performance mass spectrometers.

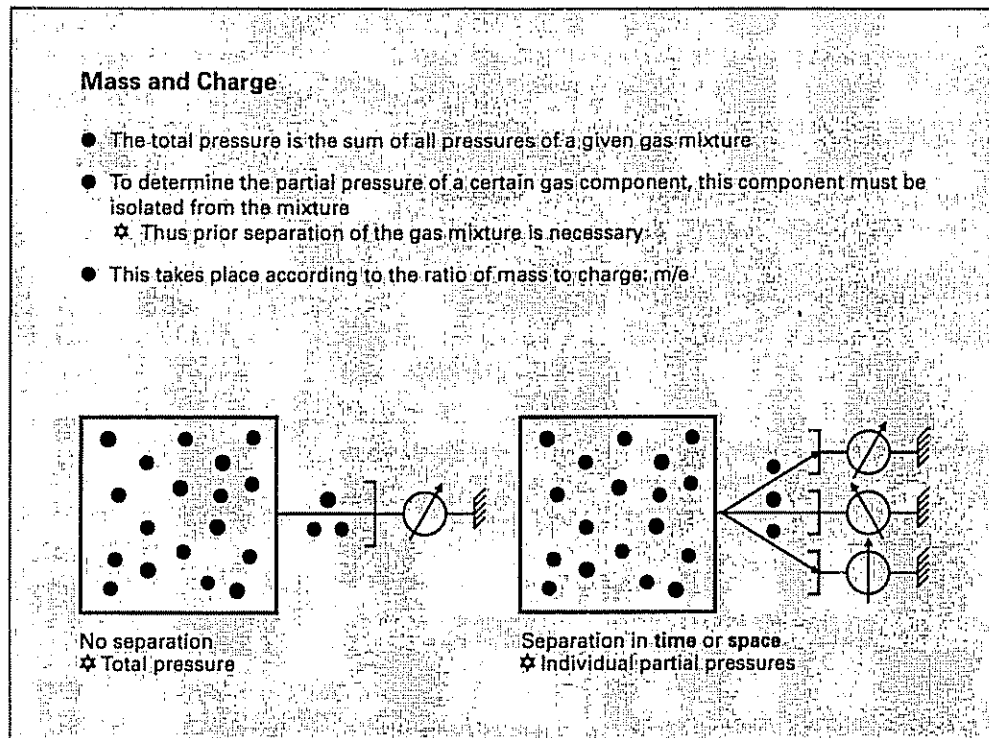


Fig. 1:  
In contrast to total pressure measurements, in mass-selective measuring methods detection is according to the mass/charge ratio of the ions.

Typical applications are:

- mass-selective leak testing of serial production components in the automotive industry
- quantitative determination of the composition and purity of process gases
- complex analysis of catalytic reactions on the surface of solid bodies
- the investigation of biochemical substance transformations.

In view of this wide range of applications it is not surprising that in the course of recent decades numerous physical methods for mass separation of particles have been developed and implemented in matured practical measuring instruments. In spite of the considerable difference of the methods, they all have a common feature. A vacuum must be generated for operating mass spectrometers, in many cases with several pressure ranges. Con-

Some examples are:

- leak detection
- partial pressure measurements in high vacuum systems
- monitoring of the gas composition in vacuum coating processes
- end point determination in vacuum etching
- mass-resolved determination of neutral particles and ions in plasma processes
- determination of gas-specific desorption and adsorption rates of materials for vacuum system components.

Chiefly *quadrupole mass filters* (Fig. 2) are used today particularly for these measuring tasks. The properties of quadrupole mass filters which are especially useful for these applications are the simple manner of scanning the entire mass range, high sensitivity, high measuring and repetition



# 1 Fundamentals of mass spectrometry

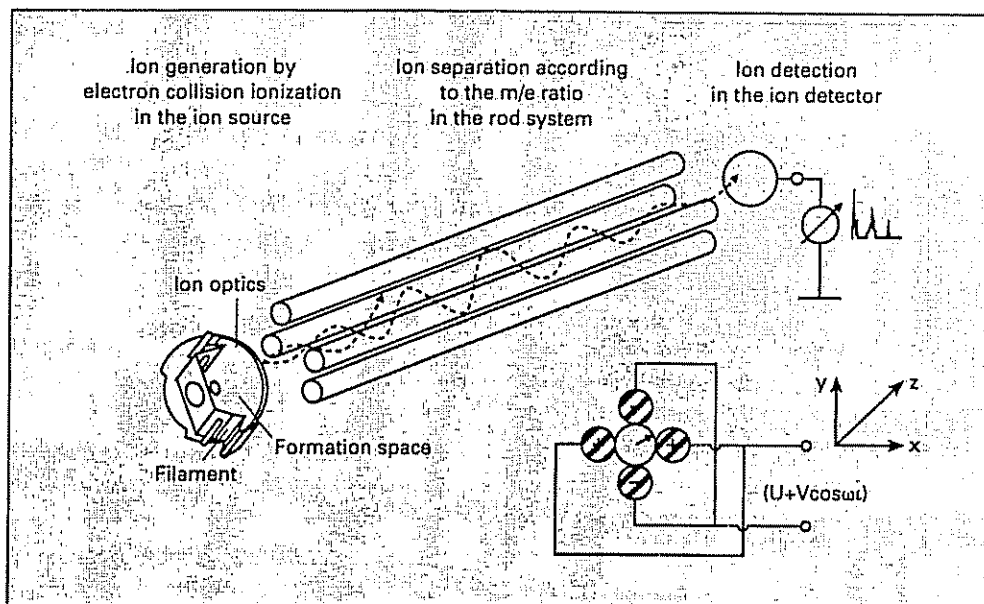


Fig 2:  
Functional principle  
of a quadrupole mass  
spectrometer.

rate, large measuring range (up to 10 decades) and compatibility with the general requirements of vacuum technology such as relatively small dimensions, arbitrary mounting position and low out-gassing rates.

A quadrupole mass spectrometer intended for partial pressure measurements is in principle an ionization vacuum gauge equipped with an additional device, the rod system, which first of all separates the types of ions produced by the ionization

process according to their mass/charge ratio ( $m/e$ ) before measuring them with an ion detector.

The ions are separated in a high frequency electric quadrupole field between the four rod electrodes with field radius  $r_0$ . The voltage between the electrodes consists of a high frequency alternating voltage  $V \cos \omega t$  and a superimposed direct voltage  $U$ . When ions are trapped in the direction of the field axis perpendicular to the plane of the diagram, they perform

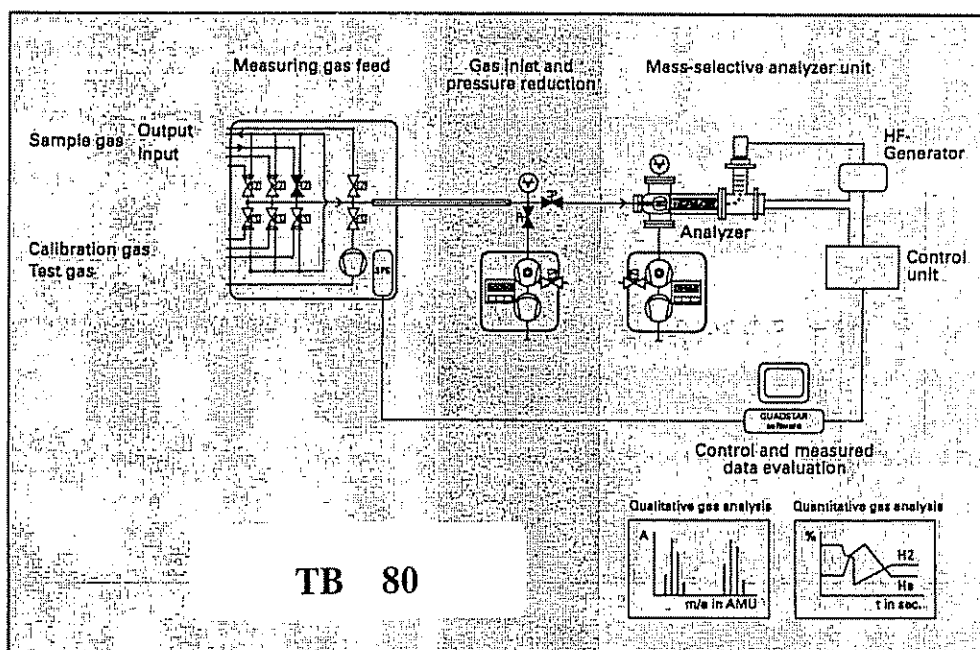


Fig. 3:  
Components for  
gas analysis  
The associated pump  
systems are described  
in detail in the catalog  
Pfeiffer Vacuum,  
Vacuum Technology  
2002-2004.

oscillations perpendicular to the field axis under the influence of the high frequency field. For certain values of  $U, V, \omega$  and  $r_0$  only ions with a particular ratio  $m/e$  can pass through the separating field and reach the ion detector. Ions which have a different mass/charge ratio are rejected by the quadrupole field and therefore cannot reach the detector. Mass/charge ratio scanning can be achieved by varying the frequency ( $m/e \sim 1/\omega^2$ ) or, as is for technical reasons almost always the case, by varying the voltages ( $m/e \sim V$ ). This gives a linear mass scale by simple means. It is also possible to adjust the resolution capability ( $\Delta m/m$ ) of a quadrupole mass spectrometer via the ratio of the magnitude  $U$  of the direct voltage component to the amplitude  $V$  of the high frequency component. It must be pointed out already at this juncture that it is always necessary to find a compromise between best possible mass resolution and high sensitivity.

Specific optimized application solutions (Fig. 3) are possible only by combining high performance mutually matched components for sample gas feed, for pressure reduction, for the actual mass spectrometer system and for the respective vacuum generating systems.

## 1.2 The quadrupole mass spectrometer

A first technically realizable variant of a quadrupole mass spectrometer was described in 1953 by W. Paul and H. Steinwedel [1, 2, 3]. The chief functional components of the mass spectrometers presented in this catalog are:

- ▶ analyzer unit (QMA) with ion source, rod system and detector
- ▶ HF generator (QMH)
- ▶ electrometer preamplifier (EP) or a pulse preamplifier (CP)
- ▶ control unit (QMS, QMI) with the quadrupole electronics (QC)
- ▶ power supply for the ion source (IS) and the high voltage power supply for a SEM detector (HV) and the computer interfaces (RS 232 C and LAN ArcNet)
- ▶ control and evaluation software (QuadStar™)

The modular construction with the various functional groups permits technically optimised equipment variants with good price to performance ratio for numerous applications, through combination of various analysers, different HF generators and specific equipment variants for the control unit. This also facilitates subsequent modification for other applications. QuadStar™ software is the common platform for the diversity of equipment versions, giving the operator a standardised user interface and the facilities for transferring measured data, measuring parameter sets and complete measuring sequences even for very different QMG systems.

Only the analyzer unit is under vacuum. It is attached via a CF flange connection, whereby the ion source (and the ion optics) as well as a part of the rod system project into the analysis chamber.

# 1 Fundamentals of mass spectrometry

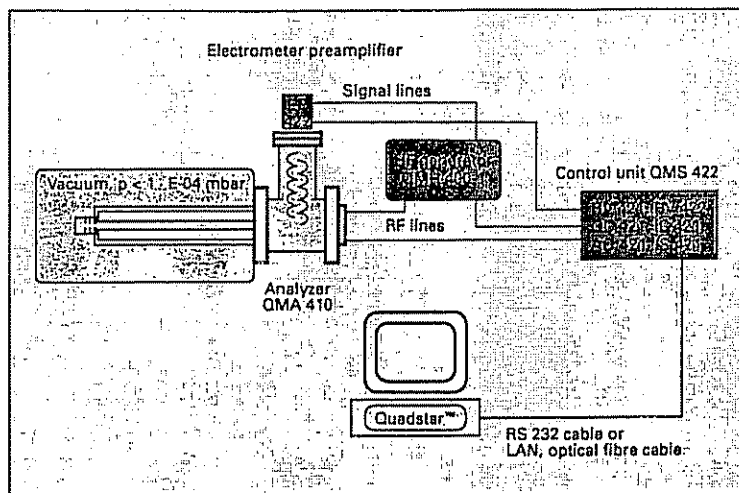


Fig. 4:  
Functional component  
units of a QMG 422.

The mounting orientation of a quadrupole analyser can be arbitrary, i.e. it can be optimally adapted to the particular application. The preamplifier is connected directly to the signal output of the ion detector via a plug connection, to minimise signal losses. The length of the HF lines and thus the possible distance between the analyzer and the HF generator is usually limited, because the parasitic capacitances of the connecting leads make a considerable contribution to the total capacitance of the HF resonant circuit. The attachment orientation of the HF generator is arbitrary, but it is necessary to ensure adequate air circulation for cooling. The control units are constructed as slide-in modules for racking systems and can accommodate further modules for analog and digital signal input/output (AO 421, AI 421, DO 421, DI 421). In addition to an internal bus system which interconnects all system components, the control units also contain their own data and parameter memories, so that the current operating mode (including set alarm points) can still run even when communication with the computer is interrupted. A local operator console CS 422 permitting operation without computer support is available for the control unit QMS 422.

In the compact units of the Prisma™ series (Fig. 5), the electronic components comprising the HF generator, the electrometer preamplifier, the quadrupole electronics, the ion source power supply, the high

voltage power supply and the data interface, are combined in a housing and directly connected to the analyzer via a disconnectable plug connection. The direct coupling of the HF generator to the rod system leads to significantly smaller HF power loss when coupling-in the high frequency field. This permits smaller power rating of the HF module for the same performance quality of the mass filter, and thus a space saving and cost effective constructional design of the entire electronics. However, there are limits to the possible utilisation of such a design if high ambient temperatures ( $> 40^{\circ}\text{C}$ ) or increased radiation stress, for example in direct attachment to elementary particle accelerators, can arise. Utilization of the Prisma™ devices down to the region of very small pressures ( $p < 1 \cdot 10^{-10}$  mbar) is possible without problems by virtue of the degassing function of the ion source, the use of suitable materials for the components under vacuum and the maximum bakeout temperature of  $300^{\circ}\text{C}$  for the analyzer when the electronics is detached.

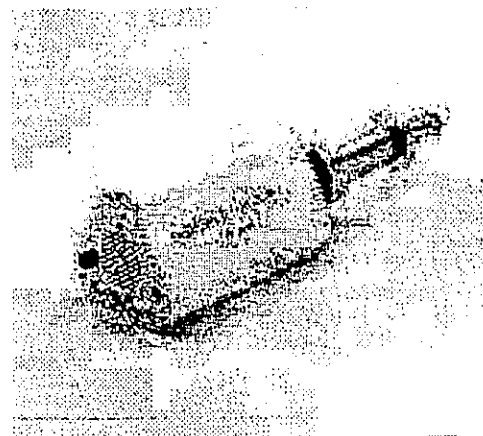


Fig. 5:  
Mass spectrometer Prisma™ M1.



### 1.2.1 The ionization process

Ionization is the part of the procedure for analysing neutral particles which has the greatest effect upon the sample gas [4, 5]. A small fraction of the atoms or molecules present in the gas phase are converted into an ionized state by bombarding them with low energy electrons. This produces singly and multiply charged positive ions. The energy of the collision electrons has a strong effect on the number and on the type of ions which are produced (Fig. 6). The ionization process of the neutral particles commences at a minimum energy (the "appearance potential") of the electrons. The number of ions produced increases rapidly with increasing electron energy, reaching a maximum at 50 – 150 eV depending on the type of gas, then falling slowly again as the energy is increased further. The yield of ions – and therewith the sensitivity – should be as great as possible, therefore electron energies in the range 70–100 eV are used in most cases. The ionic current  $i_k^+$  of a gas component  $k$  can be calculated according to the following formula:

$$i_k^+ = i^- \cdot \left( \frac{1}{s} \right) \cdot p_k \quad [\text{A}]$$

where

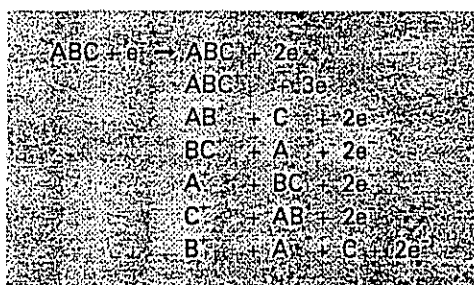
$i^-$  = Electron (emission) current [A]

$l$  = Mean free path of the electrons [cm]

$s$  = Differential ionization of  $k$   $\frac{1}{[\text{cm} \cdot \text{mbar}]}$

$p_k$  = Partial pressure of  $k$  [mbar]

For the ionization of molecules, the number of possible kinds of ions increases rapidly with increasing complexity of the molecules. Fragment ions appear in addition to singly and multiply charged molecular ions.



Rearrangement ions, such as  $\text{AC}^+$ , can appear in addition to these species. The appearance and relative abundances of the individual species of ions are characteristic for a certain kind of molecule and serve as important clues for identifying the molecule and thus for qualitative gas

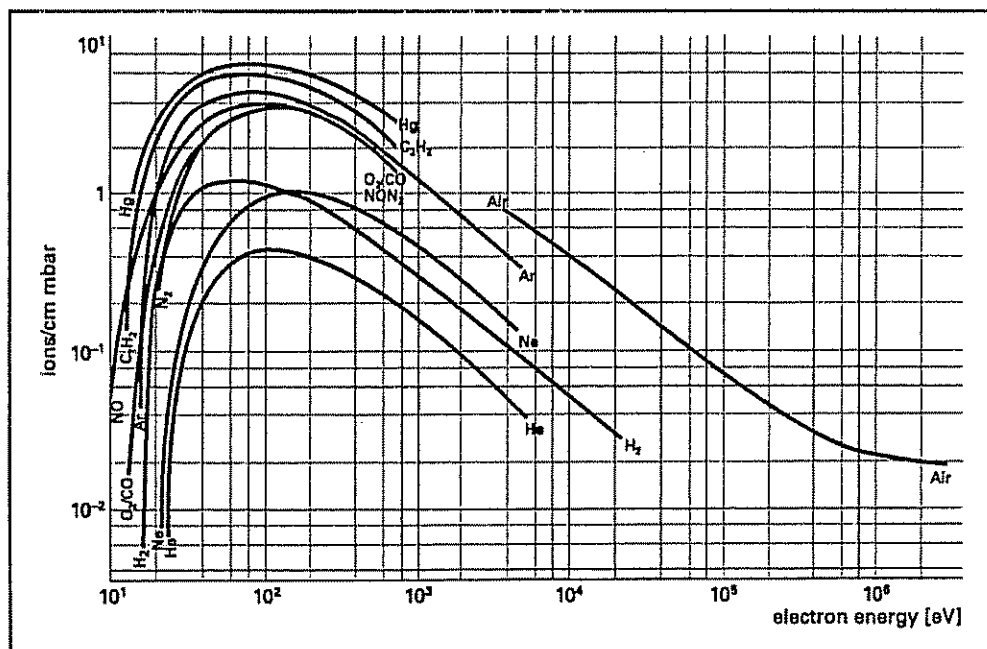


Fig. 6:  
Ionization produced  
by electron impact,  
as a function of the  
electron energy.

# 1 Fundamentals of mass spectrometry

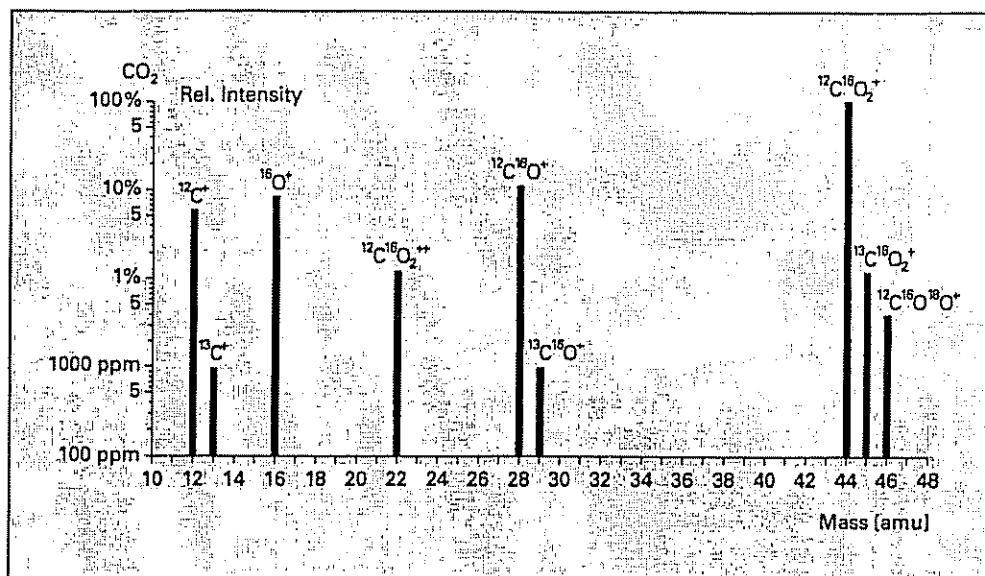


Fig. 7:  
The fragment  
distribution of CO<sub>2</sub>.

analysis. Fig. 7 below shows the distribution of fragments (fragment distribution or cracking pattern) of the simple molecule CO<sub>2</sub> recorded with 70 eV electron energy. The spectral library provided in the Quad-Star™ software contains further fragment distributions for some gases and compounds which are frequently of interest. These and other distributions taken from spectral libraries can only serve for guidance, because the actual distribution depends on various parameters such as

ionization energy, temperature and the transmission characteristics of the mass analyzer.

As shown in Fig. 8, the production of multiply charged ions can be strongly suppressed by using smaller electron energies, here < 43 eV. This effect is exploited, for example, to analyse Ar/Ne mixtures, in order to minimise the contribution to the mass number 20 produced by <sup>40</sup>Ar<sup>++</sup> and thus to achieve a lower detection threshold for <sup>20</sup>Ne on mass number 20.

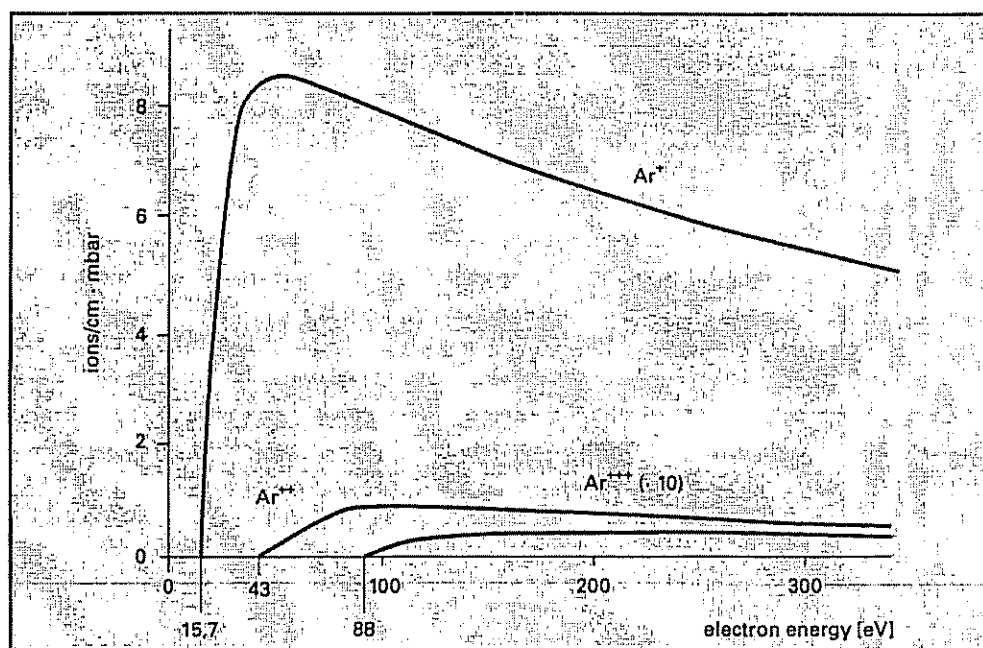


Fig. 8:  
Ionization by electron  
impact as a function  
of the electron energy  
for argon.



For all mass spectrometers described in this catalog (except for the QMG 422, QME 125 variants) the energy of the collision electrons can be varied continuously over the range 10 – 150 eV. The problem of overlapping ion currents of different origin on certain mass numbers is frequently encountered when analysing mixtures of several gas components.

Fig. 9 shows that in this example there are mass numbers whose intensity is determined exclusively by a single gas component (e.g. argon at mass number 40, oxygen at mass number 32, carbon dioxide at mass number 44, water at mass number 18).

For other mass numbers the total intensity of the detected ion current is determined by superimposition of the contributions made by various fragment ions originating from different gas components. In this example the ion current intensity on mass number 16 is determined by fragment ions from oxygen, water, carbon monoxide and carbon dioxide. Therefore this mass number is less suitable for quantitative determination of the oxygen content or oxygen partial pressure. In this example one would use instead the intensity measured at mass number 32. In this example it would be particularly difficult to determine the CO content, which could be calculated only by subtracting from the total ion cur-

rent intensity at mass number 28 the contributions of  $N_2$  (determined at mass number 14 when the fragment ion ratio  $N^+/N_2^+$  is known) and of  $CO_2$  (determined on the mass number 44 when the fragment ion ratio  $CO_2^+/CO^+$  is known).

Depending on the composition and concentration ratios of the gas mixture which is to be analysed, it is thus possible to devise suitable algorithms and calibrating procedures for a particular measuring task. Before carrying out a quantitative gas analysis, the respective calibration factors for each individual gas component must be determined by feeding suitable calibration gas mixtures with respective non-overlapping components. Thereafter the concentration and partial pressure of these gases can be determined within the scope of a matrix calculation.

The QuadStar™ software supports such matrix calculations and the required gas-specific calibration routines.

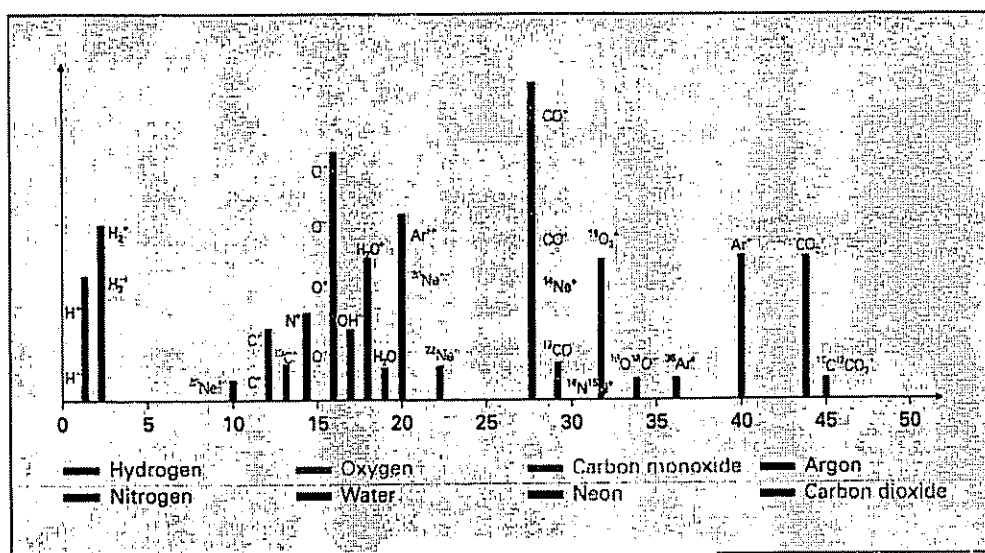


Fig. 9:  
Mass spectrum of a  
gas mixture, recorded  
with 90 eV ionization  
energy.

# 1 Fundamentals of mass spectrometry

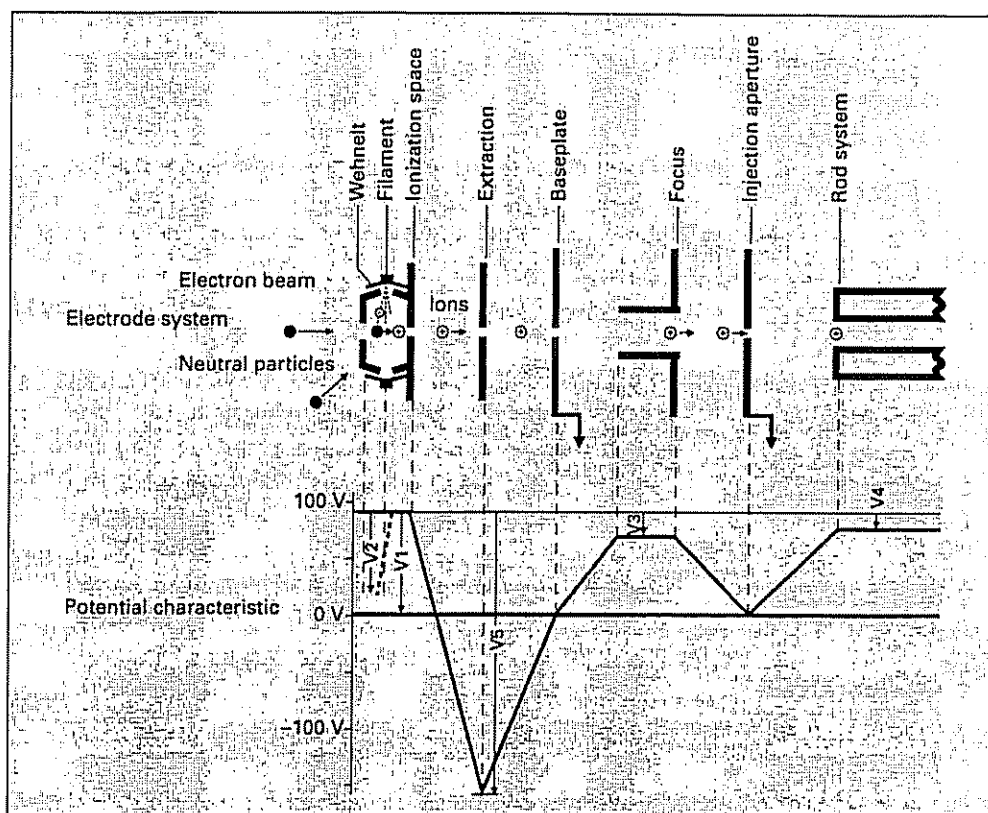


Fig. 10:  
Electrode configuration and potential characteristic of a cross-beam ion source taken as example.

## Operation of Ion Source (Fig. 10)

The neutral particles arriving in the ionizing space (formation space) are ionized by the electrons which are emitted by the filament and accelerated in the formation space. From the potential characteristics it is evident that a repelling potential always results for the electrons relative to the environment (mass frame potential), so that no electrons are emitted into the environment, and electrons are accelerated only towards the formation space. The produced positive ions are rapidly accelerated out of the formation space and then decelerated by the applied electric field down to the energies corresponding to the field axis potential ( $V_4$ ). This achieves shorter dwell times of the ions in the formation space:

- reduces undesired ion-neutrals-reactions
- faster penetration of transition fields

Except for the QMG 422, with QME 125 mass spectrometers, all voltages on the electrode configurations and the emission current can be varied continuously via the

QuadStar™ software, so that optimising the ion source for a particular measuring task is a very simple procedure.

Tungsten (W), rhenium (Re) and yttrium oxide coated iridium are used as coated iridium filament material. Tungsten filaments are preferred in the ultra-high vacuum range, or where the vapor pressure of Re could produce disturbances. It is necessary, however, to bear in mind the brittleness of tungsten filaments produced by the tungsten-carbon-oxygen cycle, i.e. through the formation of  $W_2C$ . Yttrium oxide coated iridium is used increasingly instead of the former pure metal filaments. The advantages of these filaments are the considerably lower operating temperature and the relative insensitivity to air in-rush. Consequently the preferred application fields for these filaments are analysis of thermally sensitive substances (such as metal-organic compounds) or the analysis of impurities in gas mixtures which contain a large oxygen fraction.

Different constructional designs of the ion sources have been developed in order to

establish best matched conditions of mass spectrometry for the various measuring tasks. The following illustrations show the chief types of ion sources for the mass spectrometers described in this catalog.

#### Axial Ion Source (Fig.11)

Electron beam orientation and ion extraction in the axial direction ensure high sensitivity and good injection conditions for the ions into the downstream quadrupole separating field. The preferred application field for this rugged ion source is residual gas analysis. The filament is made of rhenium or tungsten.

#### Grid Ion Source (Fig.12)

The special selection of materials in conjunction with the open construction give

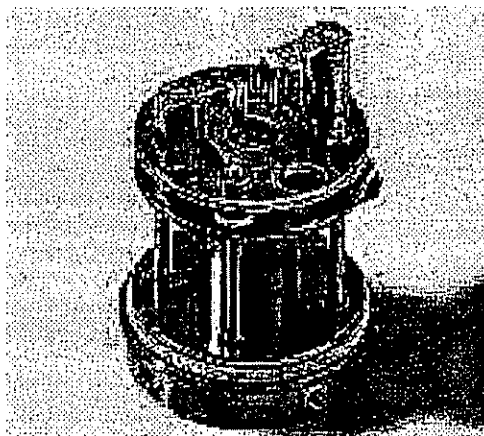


Fig. 11: Axial ion source.

the grid ion source very low desorption rates. This ion source also has the important advantage of easy degassing by electron bombardment. Possible applications are therefore residual gas analysis and partial pressure determination in the ultra high vacuum field (Fig. 13), as well as desorption measurements. Two filaments are available in the form of the ring cathode with centre tap. By virtue of its low vapor pressure, tungsten is the preferred filament material for this ion source.

During measurements in the pressure range  $< 10^{-10}$  mbar the "EID ions" mentioned above can be observed [6]. When surfaces

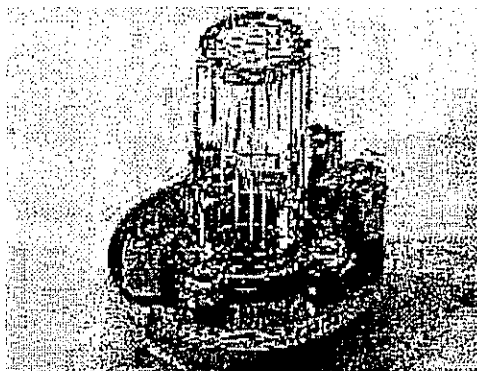


Fig. 12: Grid ion source for extreme ultra high vacuum measurements.

are bombarded with electrons, a number of species such as  $H^+$ ,  $O^+$ ,  $F^+$ ,  $Cl^+$  are desorbed directly, often with high yield. EID ions originate from adsorbed layers whose cause is often found in the history of the ultra high vacuum apparatus or of the ion source, and they usually have an initial energy of a few eV. This property can be exploited for distinction with respect to ions from the gas phase (Fig. 13). Based thereon, Redhead has proposed the "extractor" tube for total pressure measurement, giving good discrimination with respect to ions with initial energy [7]. The quadrupole mass spectrometer can be combined with a grid ion source with a similar functional principle. The mass numbers 1, 16, 19, 35, 37, which are typical for EID ions, in most cases have only very limited significance for residual gas analysis. All gases which contribute to these peaks can also be detected on other mass numbers.

Fig. 13: UHV spectrum recorded with the QMA 125 grid ion source and  $90^\circ$  off axis SEV and QME 125-1, (1-100 AMU)

